Status of the Optical Replica Synthesizer Experiment

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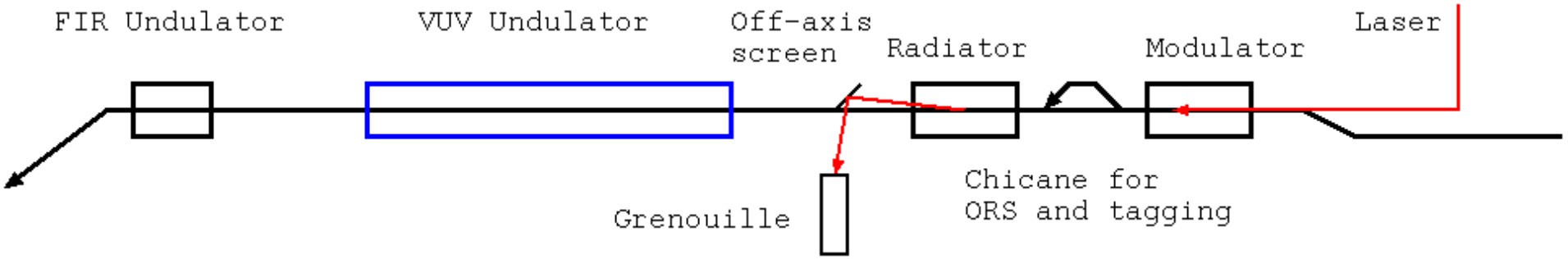
What and How

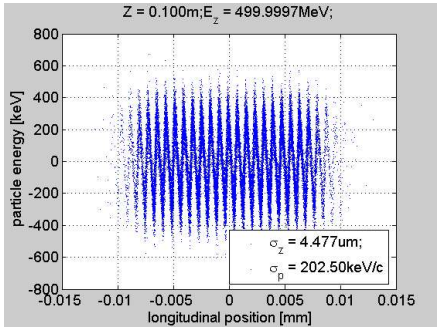


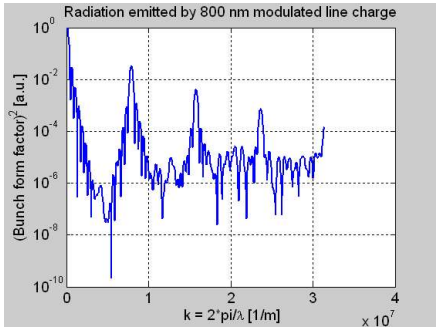
- Measure the longitudinal bunch profile of the femto-second long electron bunches (Saldin, Schneidmiller, Yurkov: NIM A 539 (2005) 499.)
- Energy modulation via (v.E) coupling
- Longitudinal density modulation in chicane
- Cause coherent emission of light pulse in radiator that mimics the longitudinal shape of the electron bunch (optical replica).

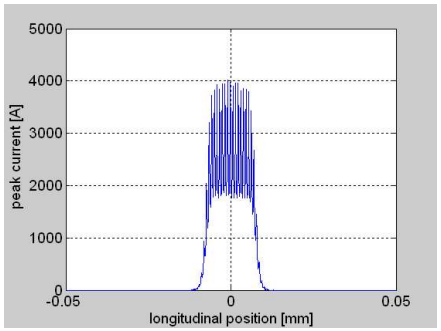
What else can we do with it

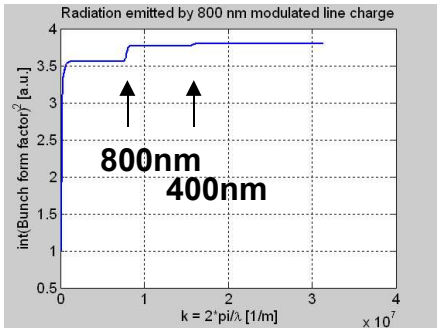
- Second coherent pulse from FIR undulator or radiator for time-stamping (Bunch in modulator and use the FIR to generate coherent pulse synchronized with the beam that can be mixed with the pump-probe laser)
- Coherent transition radiation from modulated electron beam (Poor man's replica)
- Interaction of laser and electron beam
- Laser heater is very similar to modulator+laser
- Affecting VUV-FEL laser pulse length by locally tickeling the electron bunch profile, therby shaping the peak current. (SciFi?)

Coherent transition radiation from OTR2sund3



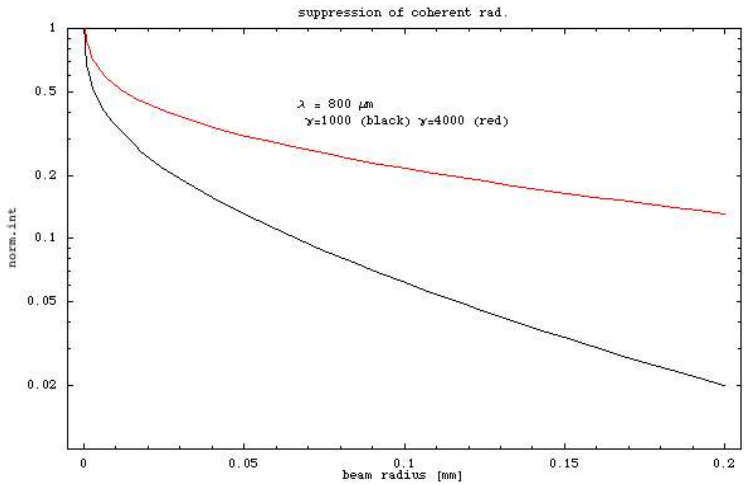






Holger Schlarb, DESY

- OTR screen following the chicane can be used to observe transition radiation at the modulation frequency 800 nm (TiSa).
- Huge enhancement from the form factor of unmodulated bunch
- Reduction by a factor of 10 due to finite beam size (B. Schmidt).



Component List

- Seed Laser, hutch, optical table, optical transport
- Two undulators and power supplies
- Chicane and power supplies
- Laser Diagnostic, Grenouille
- Extra beam diagnostics
- Person-power
- Good-will
- Help

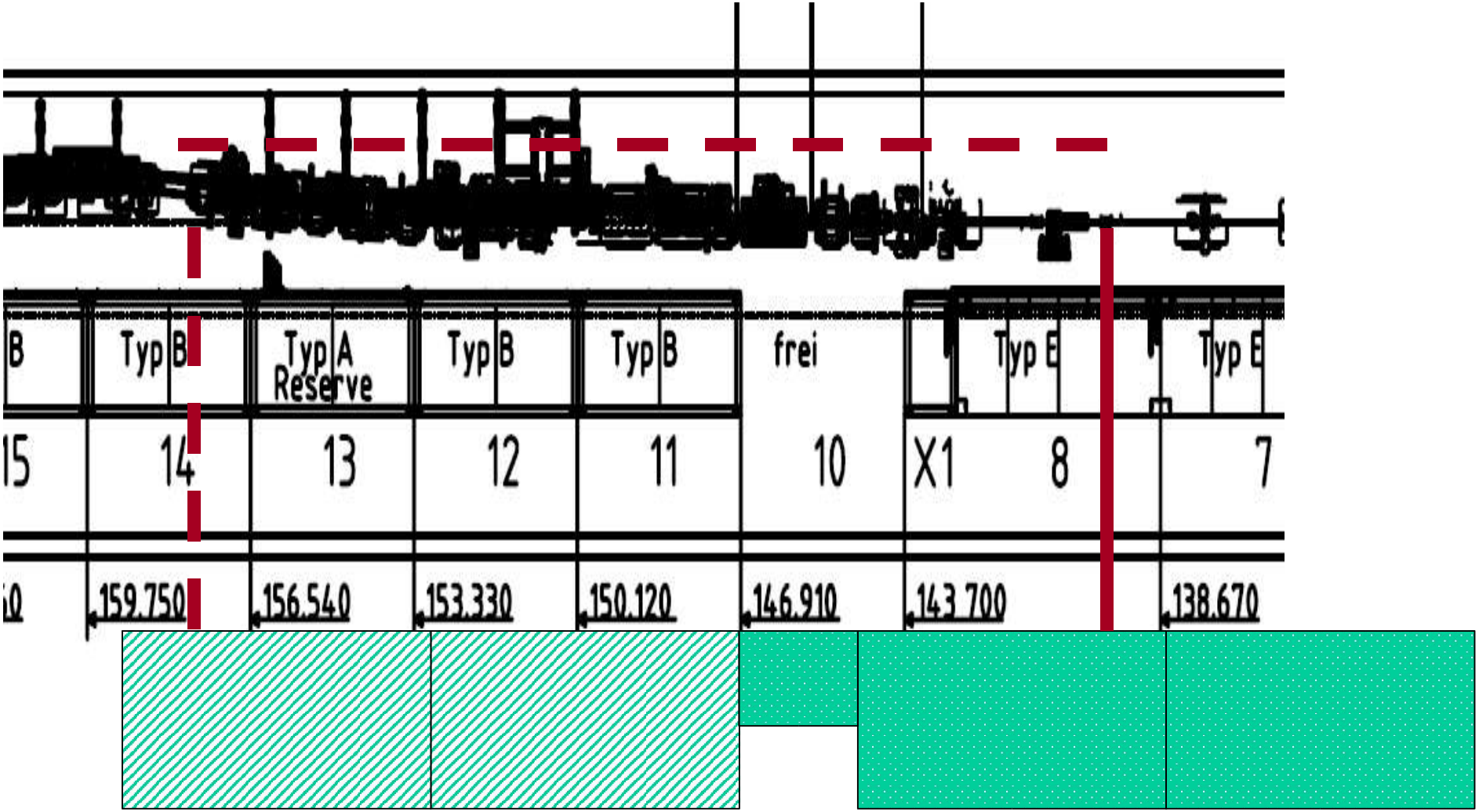
Seed Laser

- Peter van der Meulen (SU) and Axel Winter (DESY)
- Synchronized Er-fiber oscillator with frequency doubler from DESY
- CPA2001 Ti:Sapph amplifier from Stockholm University
- Internals (stretcher and compressor gratings) of CPA are unknown and grating misalignments may results in chirped and tilted pulses.
- Parameters:
  - Length = 2 ps (FWHM)
  - Energy/pulse=0.25 mJ, Peak field = 1.8 10^8 V/m
  - Width = 0.75 mm (FWHM)

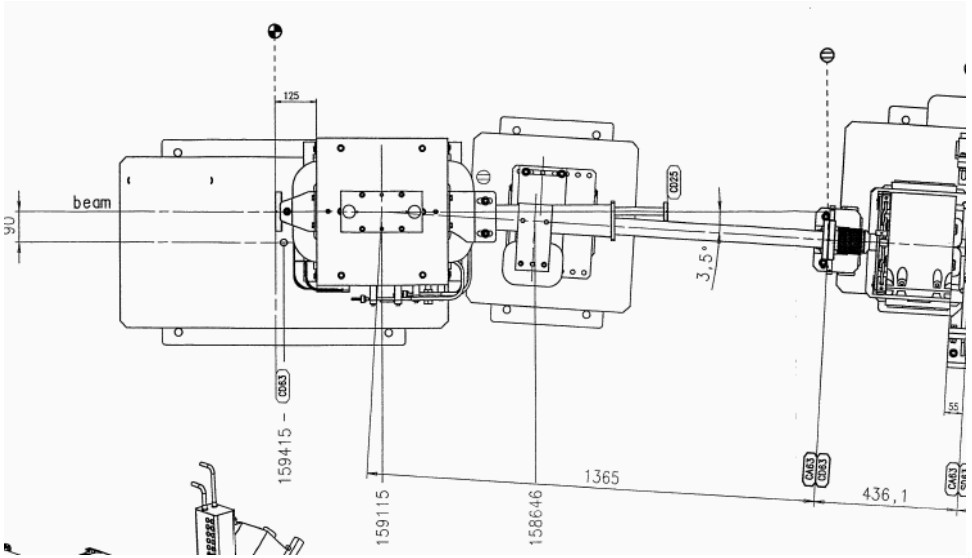
Laser Infrastructure

- External Laser hutch adjacent to the existing hut.
- Use the same hole into the tunnel at 139 or another hole close to the chicane.
- Distance from laser to vacuum window ~ 50 m.
- Evacuated laser beam line from hole to vacuum window (diameter = 16 mm) at 158.2 m.
- Characterizing the laser beam with Grenouille near the vacuum window.
- Alignment and monitoring.

Additional laser hutch & second tunnel

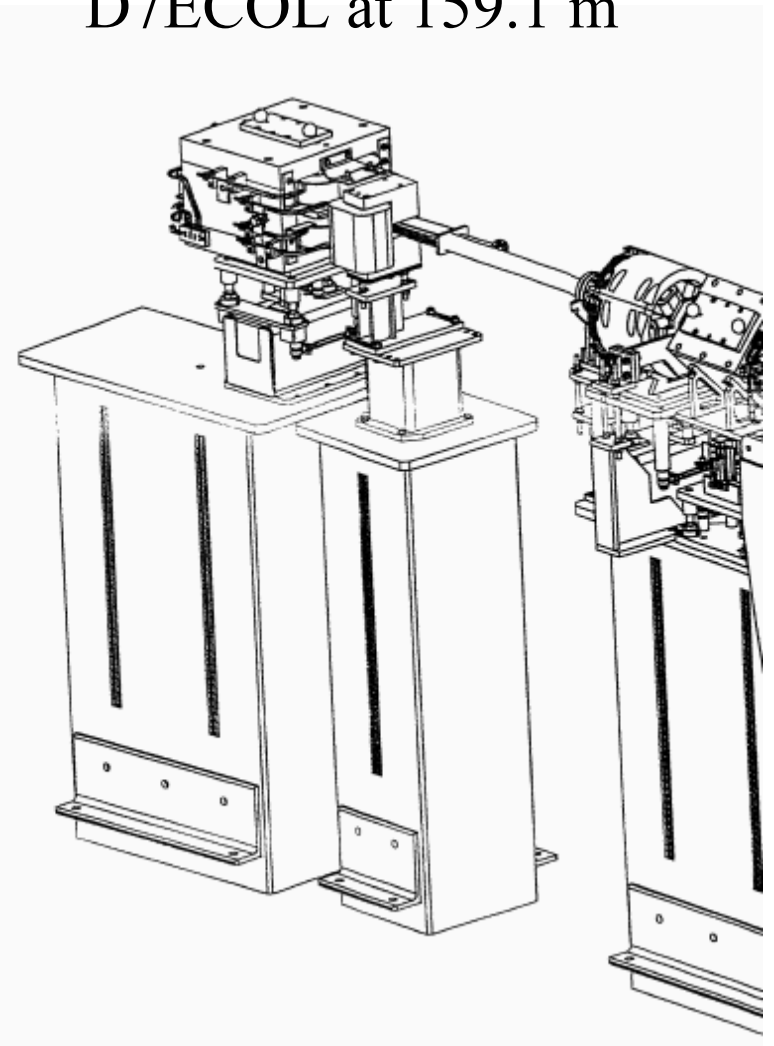


Seed Laser Vacuum Interface and Characterization and Alignment



- Need to characterize seed laser with nearby GRENOUILLE
- Alignment of the laser requires more thought, possibly with remotely controlled mirrors and diodes.
- Matching of the waists with remotely controlled lenses.
- Monitoring during operation.

Laser feed just upstream D7ECOL at 159.1 m



Undulators

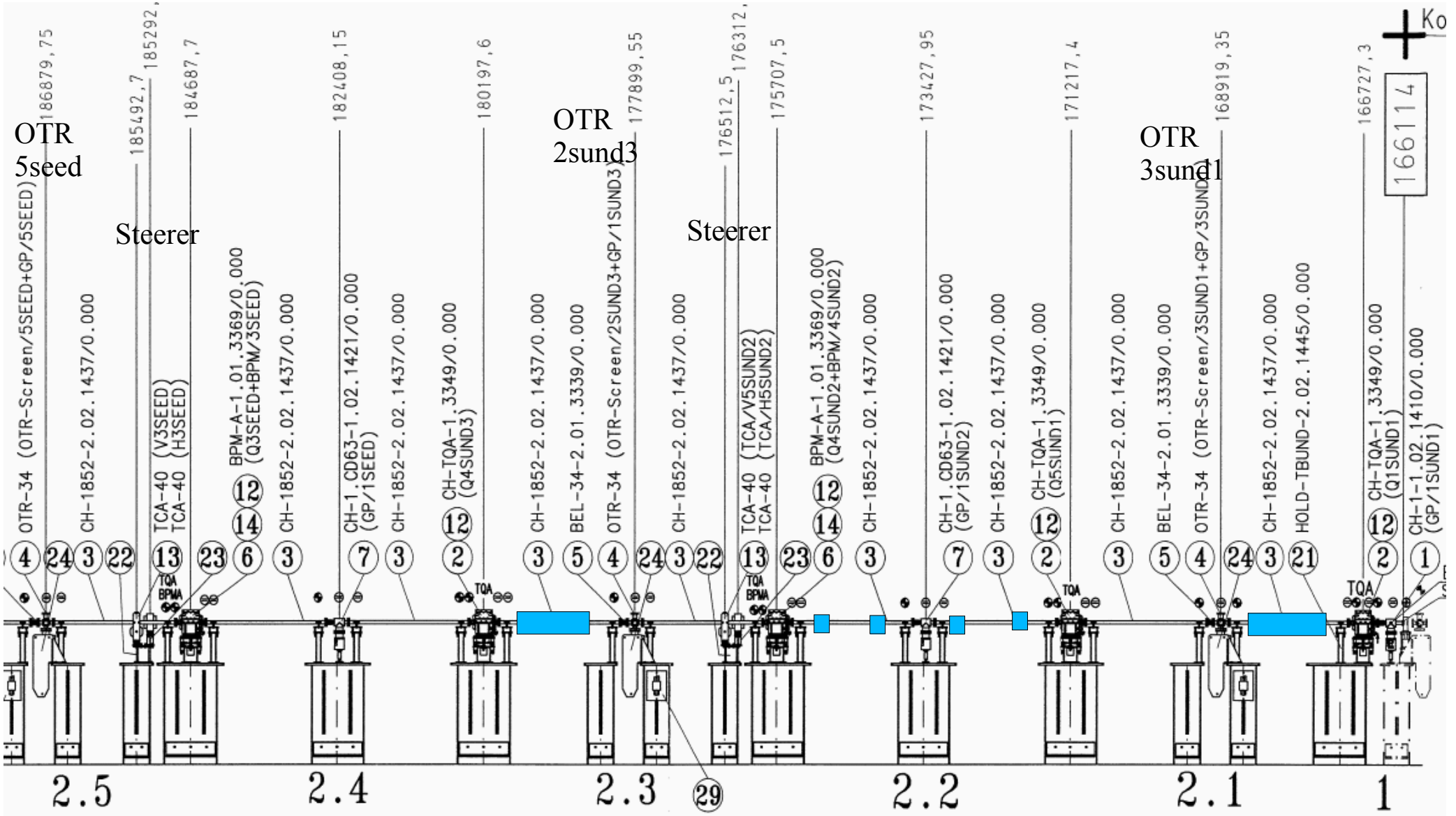
Parameter	Value
Type	Electromagnetic
Number of undulator	1-2 (vert + horiz)
Gap	40 mm
Period length	200 mm
Pole length/width	50/100 mm
Number of full periods	5
Number of poles	14
Nominal field	0.31 T
Nominal K-Value	5.7
Maximal field	0.42 T
Maximum K-Value	7.7
Iron yoke length	1400 mm
Overall length incl. coils	< 1500 mm
Ampere-turns per coil	to be decided
Number of turns	to be decided
Maximal current	< 400 A, better < 100 A
Number of basic / end coils	10 main, 4 end coils
Vacuum chamber diameter	35 mm
First field integral	5×10^{-5} Tm
Second field integral	2×10^{-4} Tm^2

- Working on a tender for one or two undulators
- Should go out within a week or so

Separating the (strong, mJ) seed laser from the (weak, μJ) replica pulse

- Orthogonal polarization from crossed undulators.
- Modulator vertically polarized. (Separation of the spontaneous radiation from dog-leg dipole with horizontal polarization)
- Radiator horizontally polarized.
- Absorb the seed laser in the chicane.
- Higher harmonics problematic: The TiSa 800 nm has 2^{nd} harmonic 400 nm, which cannot be phase-matched in the BBO.

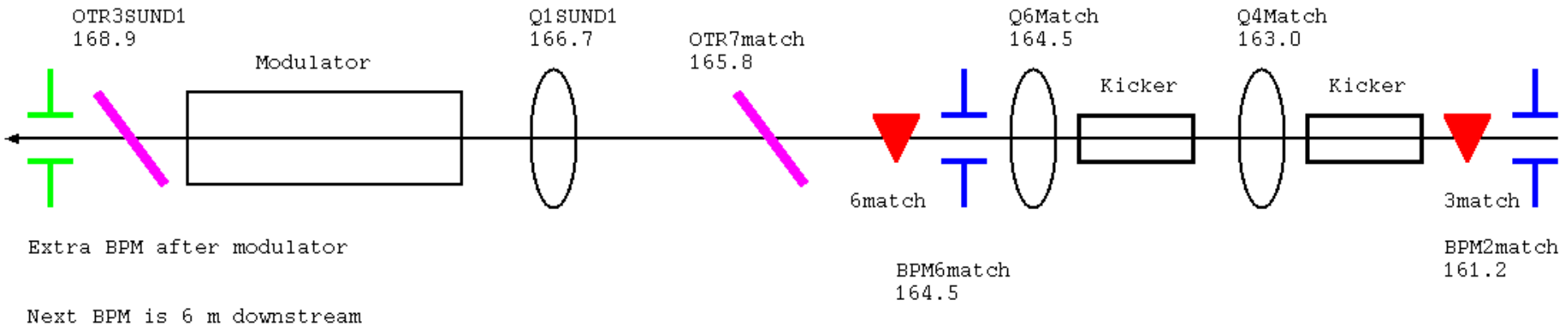
Magnet Positions, etc



Position of interest, approximately

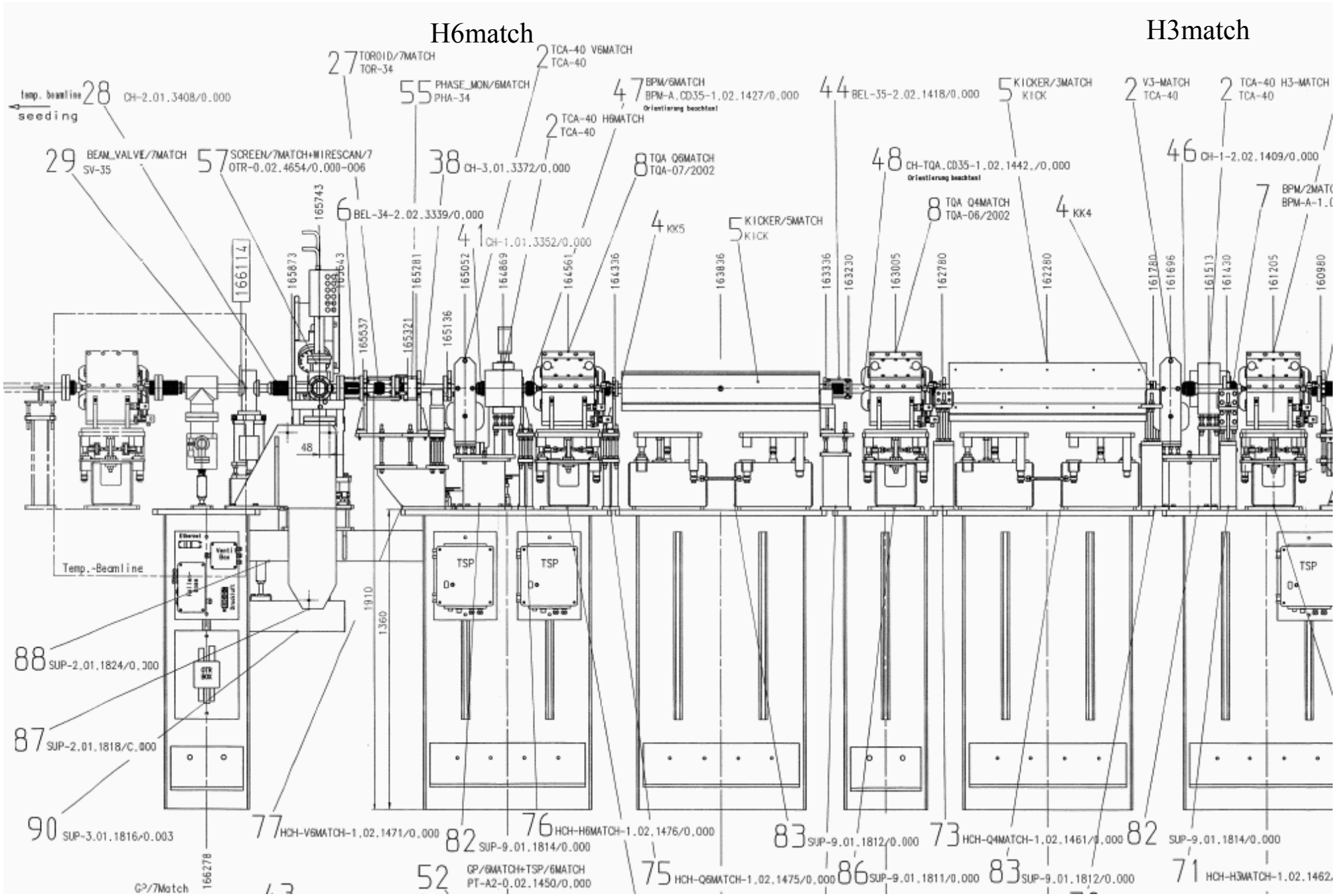
- Vacuum window 158.2
- Modulator start 167.0
- Chicane 171.5, 172.9, 174.8, 175.3
- Radiator start 178.2
- Existing OTR screens
  - 7match 165.8 (overlap)
  - 3sund1 168.9 (overlap)
  - 2sund3 177.9 (CTR)
  - 5seed 186.9 (extract)
  - 14seed 195.8
- Existing BPM
  - 2match 161.2
  - 6match 164.7 (modulator)
  - Q4sund2 175.7
  - Q3seed 184.7
  - Q12seed 193.7
  - Q20seed 201.7
- Existing steering magnets
  - 3match 161.5 (modulator)
  - 6match 165.0 (into modulator)
  - 5sund2 176.3 (into radiator)
  - 3seed 185.3 (out radiator)
  - 12seed 194.3
  - 19seed 200.6

Alignment of electron beam in Modulator



- Two steering magnets (3match + 6 match) available, R12s are approx 2 and 5 m, seems OK.
- OTR screens (7match and 3sund1) near the modulator for overlap determination.
- One BPM downstream of modulator requested for alignment.

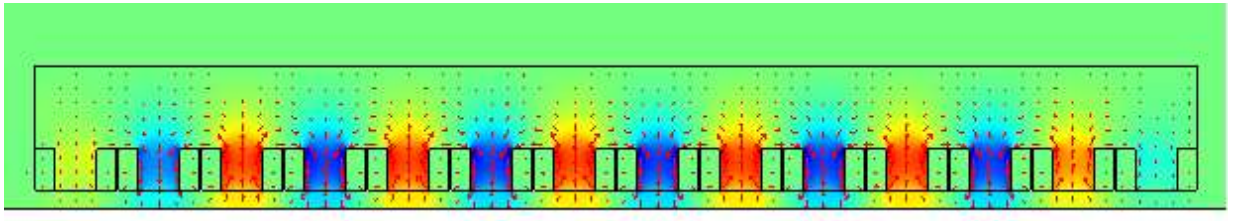
Section just before the Modulator



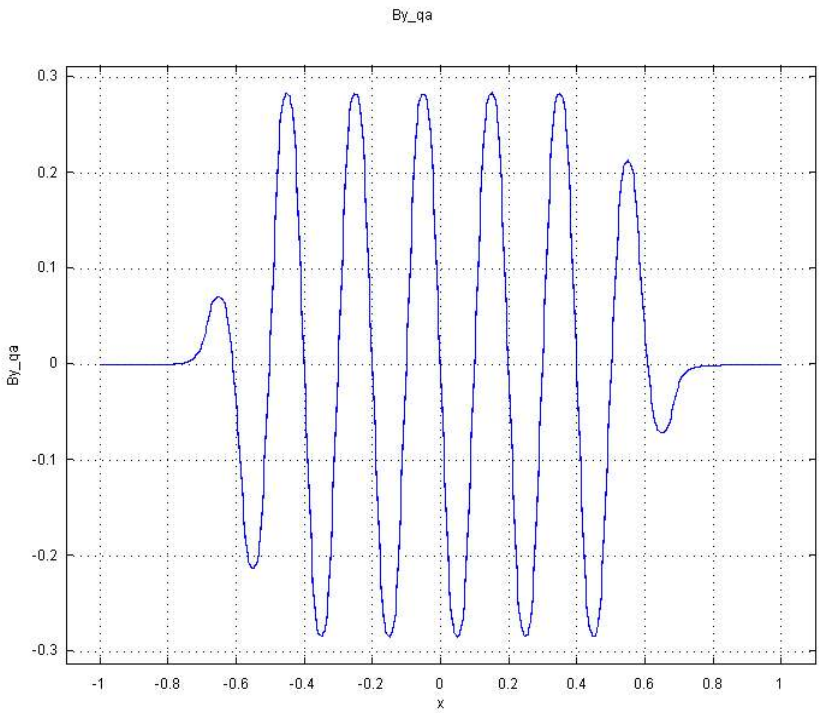
Chicane

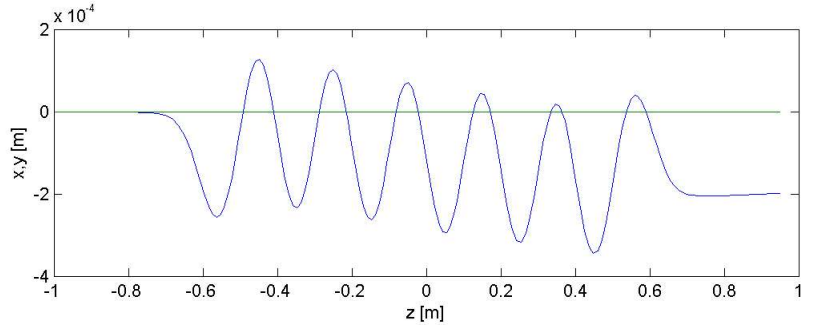
- Transform energy- into density-modulation.
- Use for ORS but also for timing/tagging in conjunction with FIR undulator.
- 1.5m between dipoles
- 10 mrad (33 10^{-3} Tm @ 1 GeV)
- R56 $\approx$ 2 x 1.5 x θ^2 = 300 micron
- maximum displacement $\approx$ 15 mm @ 300 micron
- maximum displacement $\approx$ 7.5 mm @ 75 micron
- Place mirror to extract seed laser in chicane.

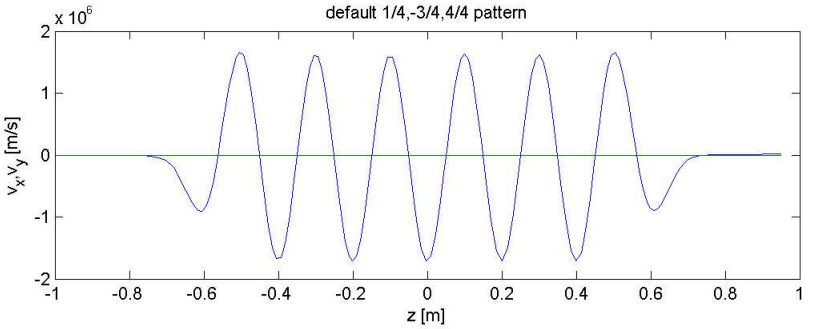
Radiator Field, Integrals and Orbit



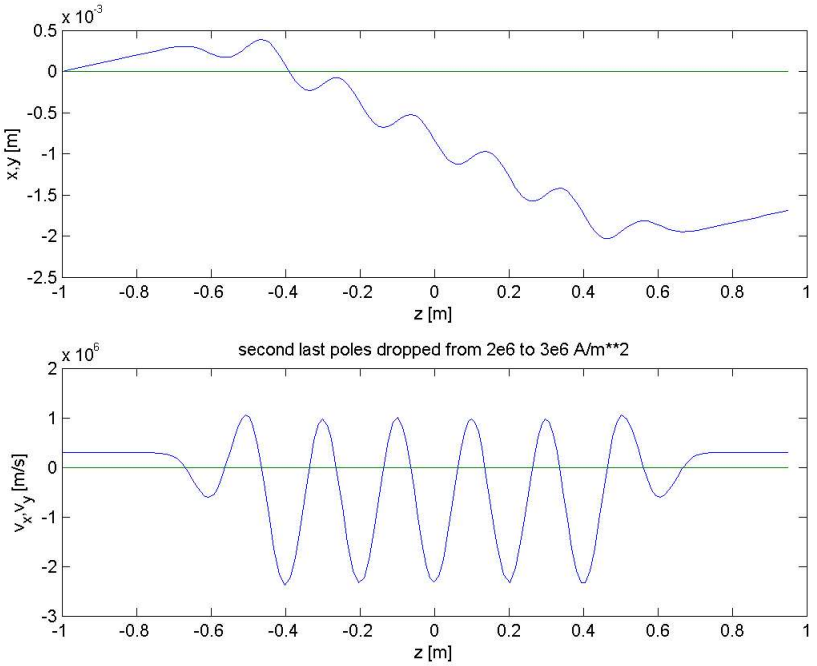
- 2-D model with FEMLAB
- Integrate Lorentz force equation with MATLAB yields field integrals and orbit (± 150 microns)

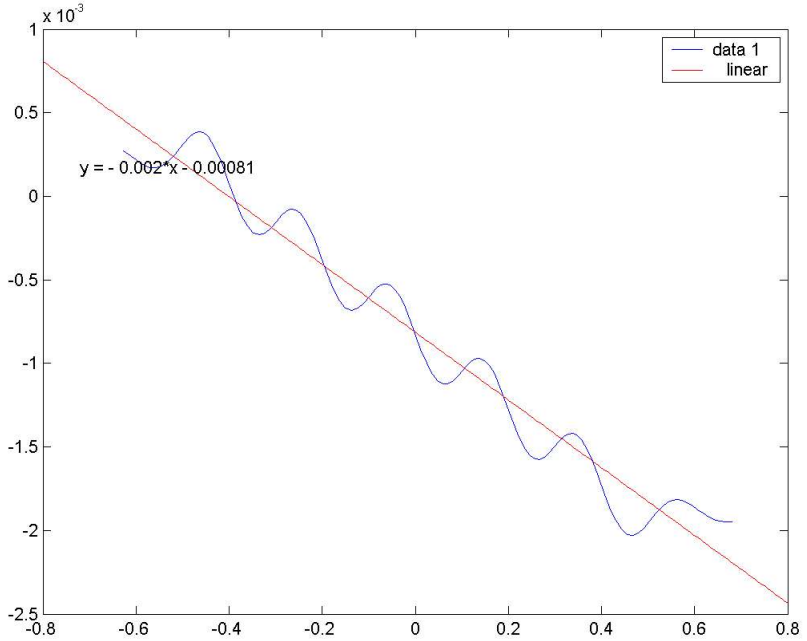






Aim for off-center screen near OTR5seed



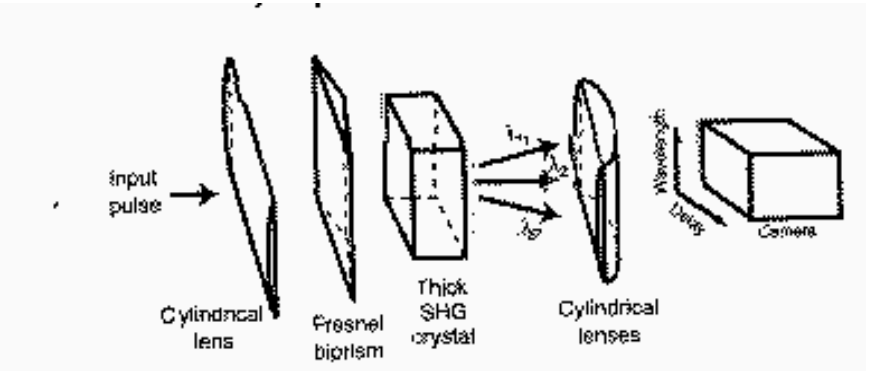


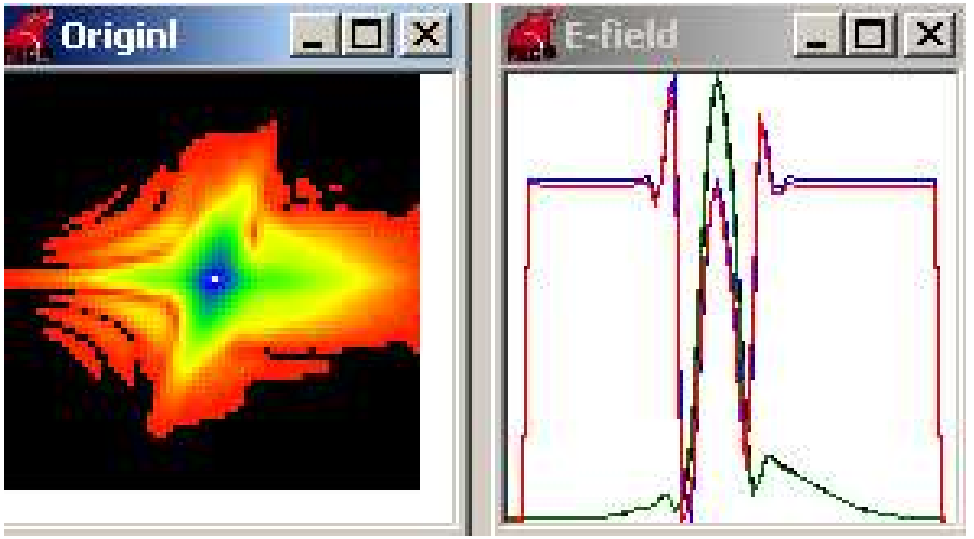
- Change excitation of second to last pole from 3 10^6 to 2 10^6 A/m^2.
- 2 mrad angle of the orbit in the radiator easily achievable.
- Yields about 14 mm offset at screen OTR5seed (186.9 m).
- Need at least two steerers to provide about 1 mrad incoming angle (H5sund2 and last dipole of chicane)
- Clean up orbit with second to last coil in radiator and H3seed.

Diagnosis of Replica Pulse in Grenouille

- *Cyclidrical lens* makes horizontal strip
- *Fresnel biprism* creates crossing wavefronts in thick *SHG crystal* → auto-correlator
- Effective thickness of SHG crystal varies with viewing angle
  → Spectrally resolved
- Second double cylidrical lens images onto camera
- Horizontally → time
- Vertically → spectrum
- Possible to reconstruct electric field profile in software from R. Trebino's book on FROG.

- Picture from Trebino's book





Conclusion

- Generate an optical replica of the longitudinal bunch profile and diagnose with laser methods.
- Key locations in VUV-FEL identified
- Moderate changes in the beam line
- Stringent time window. Must be installed during summer 2007
- Need to order the undulators a.s.a.p.